US010394654B2

(12) **United States Patent**
Ganesan et al.

(10) **Patent No.: US 10,394,654 B2**
(45) **Date of Patent: Aug. 27, 2019**

(54) METHOD AND APPARATUS FOR HYBRID FIRMWARE BOOT

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 179 days.

(21) Appl. No.: **15/475,941**

(22) Filed: **Mar. 31, 2017**

(65) **Prior Publication Data**

US 2018/0285126 A1 Oct. 4, 2018

(51) **Int. Cl.**

G06F 1/24	(2006.01)
G06F 15/177	(2006.01)
G06F 11/14	(2006.01)
G06F 12/02	(2006.01)
G06F 9/4401	(2018.01)
G06F 8/654	(2018.01)

(52) **U.S. Cl.**
CPC ***G06F 11/1435*** (2013.01); ***G06F 8/654*** (2018.02); ***G06F 9/4401*** (2013.01); ***G06F 9/4403*** (2013.01); ***G06F 12/0238*** (2013.01); *G06F 2212/202* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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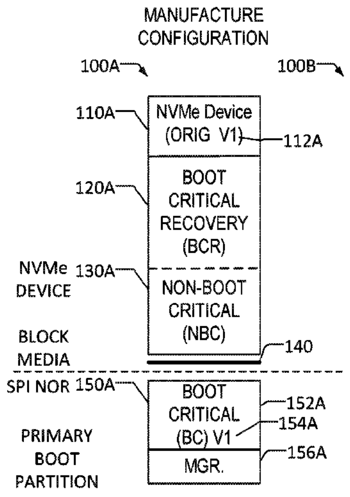
(57) **ABSTRACT**

A computer boot apparatus and related method use a primary boot component (PBC) that is fixedly mounted in the computer. The PBC has a firmware element that is a non-volatile memory comprising a boot critical portion with instructions that initiate a boot of the computer. The PBC also has a policy manager and a version identifier. The PBC initializes the computer boot via the boot critical portion. The policy manager verifies and authenticates a secondary boot component that is removably attached to the computer.

21 Claims, 5 Drawing Sheets



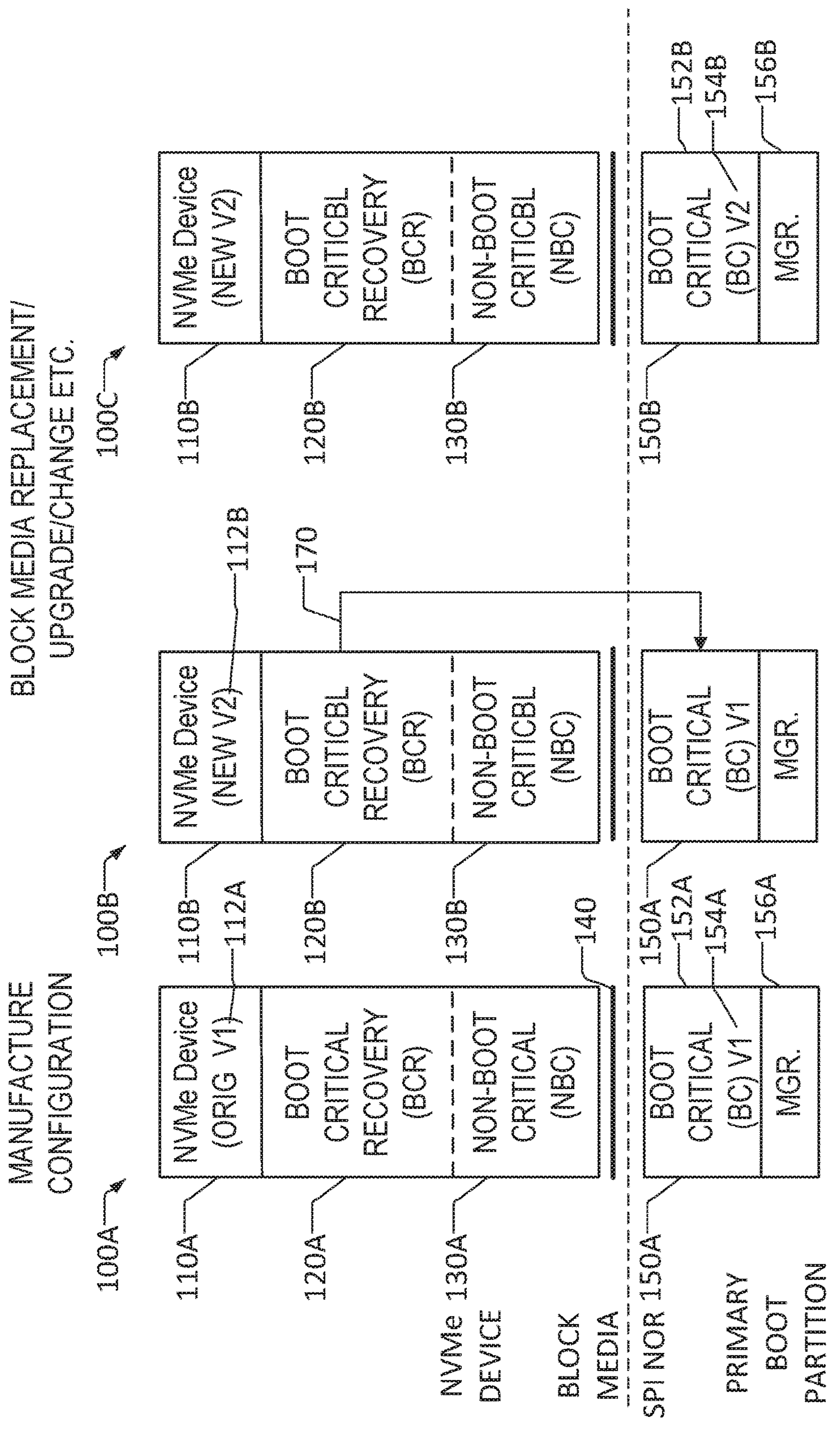


FIG. 1

FIG. 2

FIG. 3

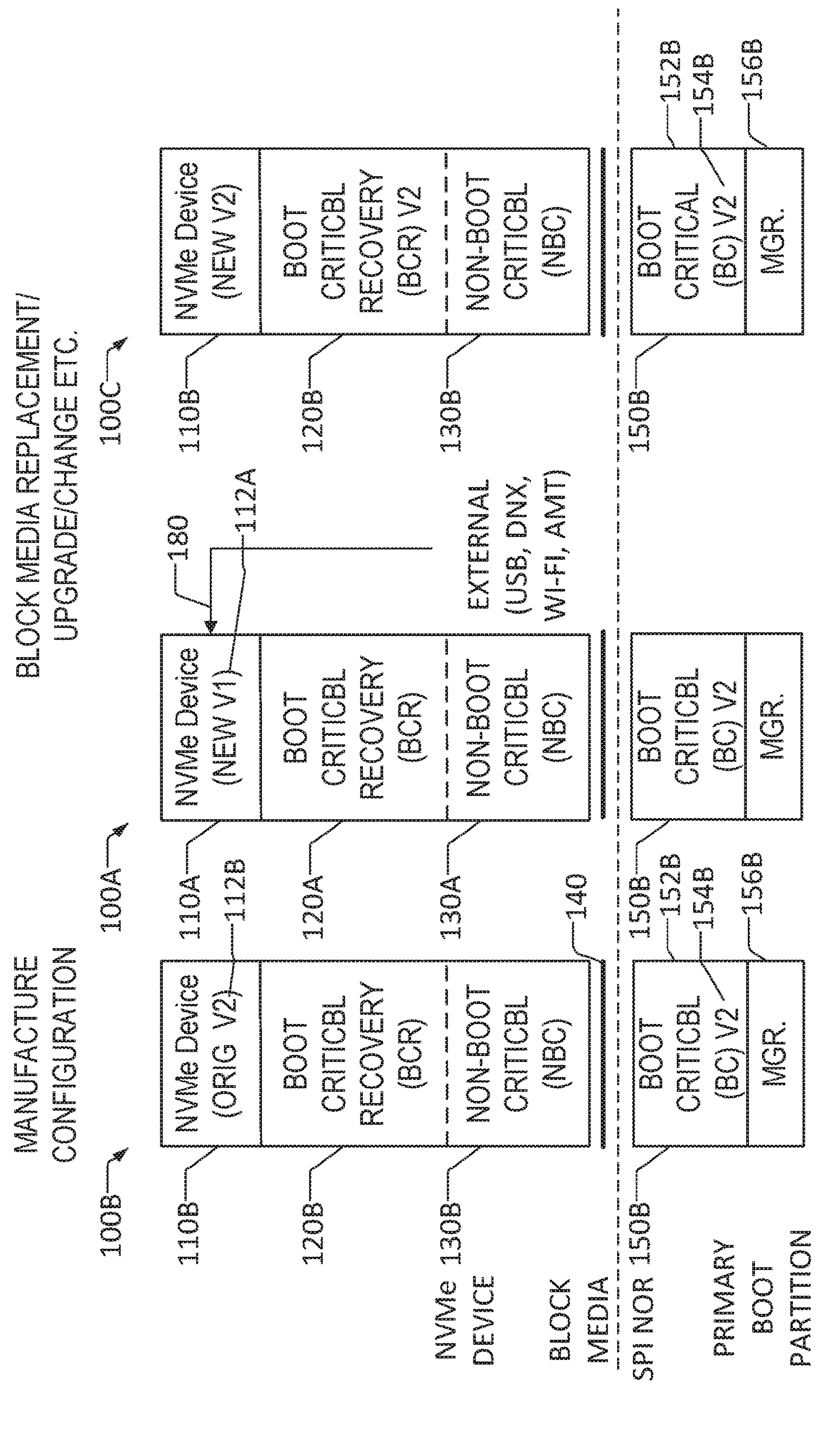


FIG. 4

FIG. 5

FIG. 6

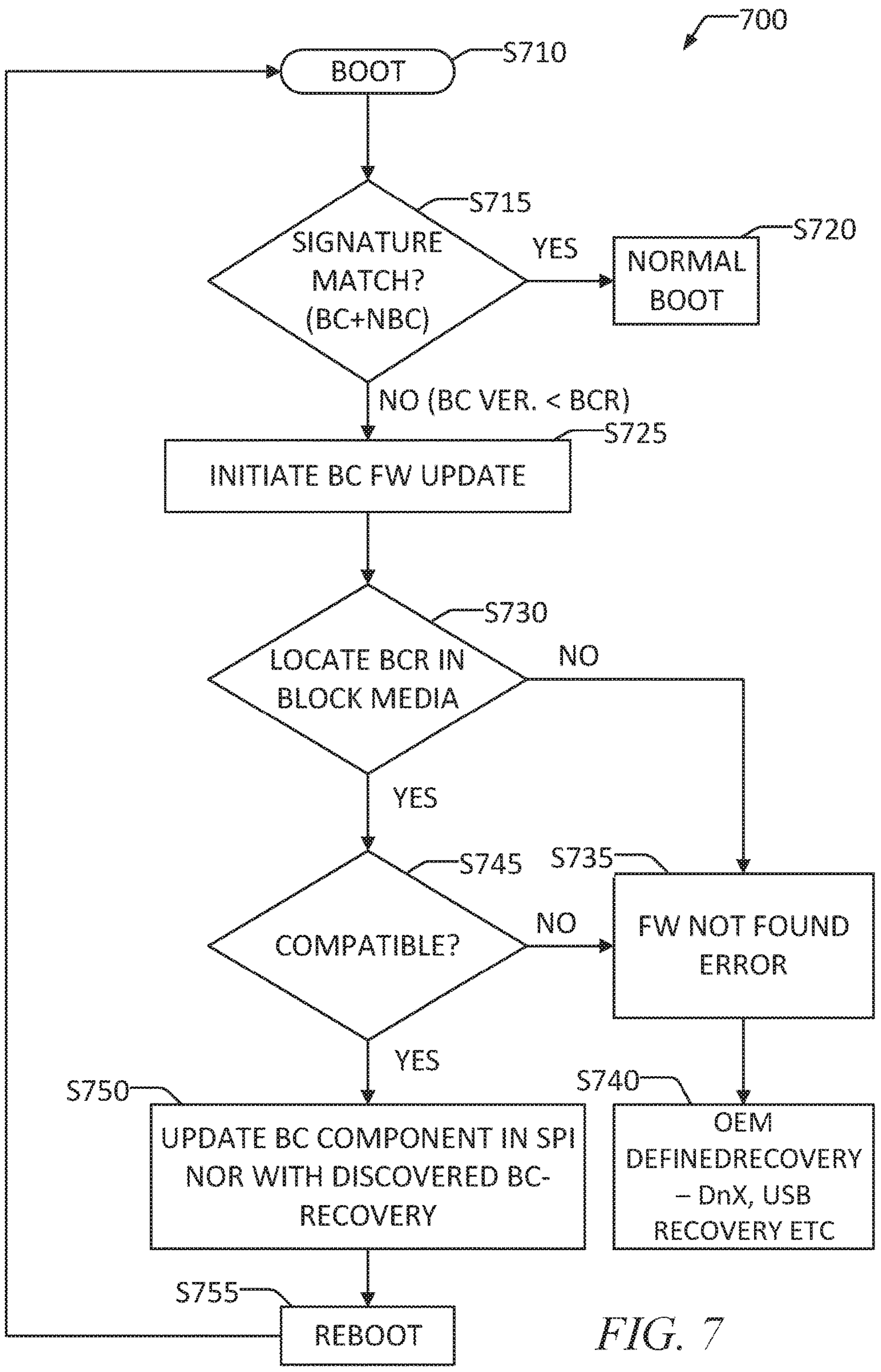

700
BOOT
S710
SIGNATURE MATCH? (BC+NBC)
S715
YES
NORMAL BOOT
S720
NO (BC VER. < BCR)
INITIATE BC FW UPDATE
S725
LOCATE BCR IN BLOCK MEDIA
S730
NO
YES
COMPATIBLE?
S745
NO
FW NOT FOUND ERROR
S735
YES
S750
UPDATE BC COMPONENT IN SPI NOR WITH DISCOVERED BC-RECOVERY
S740
OEM DEFINEDRECOVERY – DnX, USB RECOVERY ETC
S755
REBOOT

FIG. 7

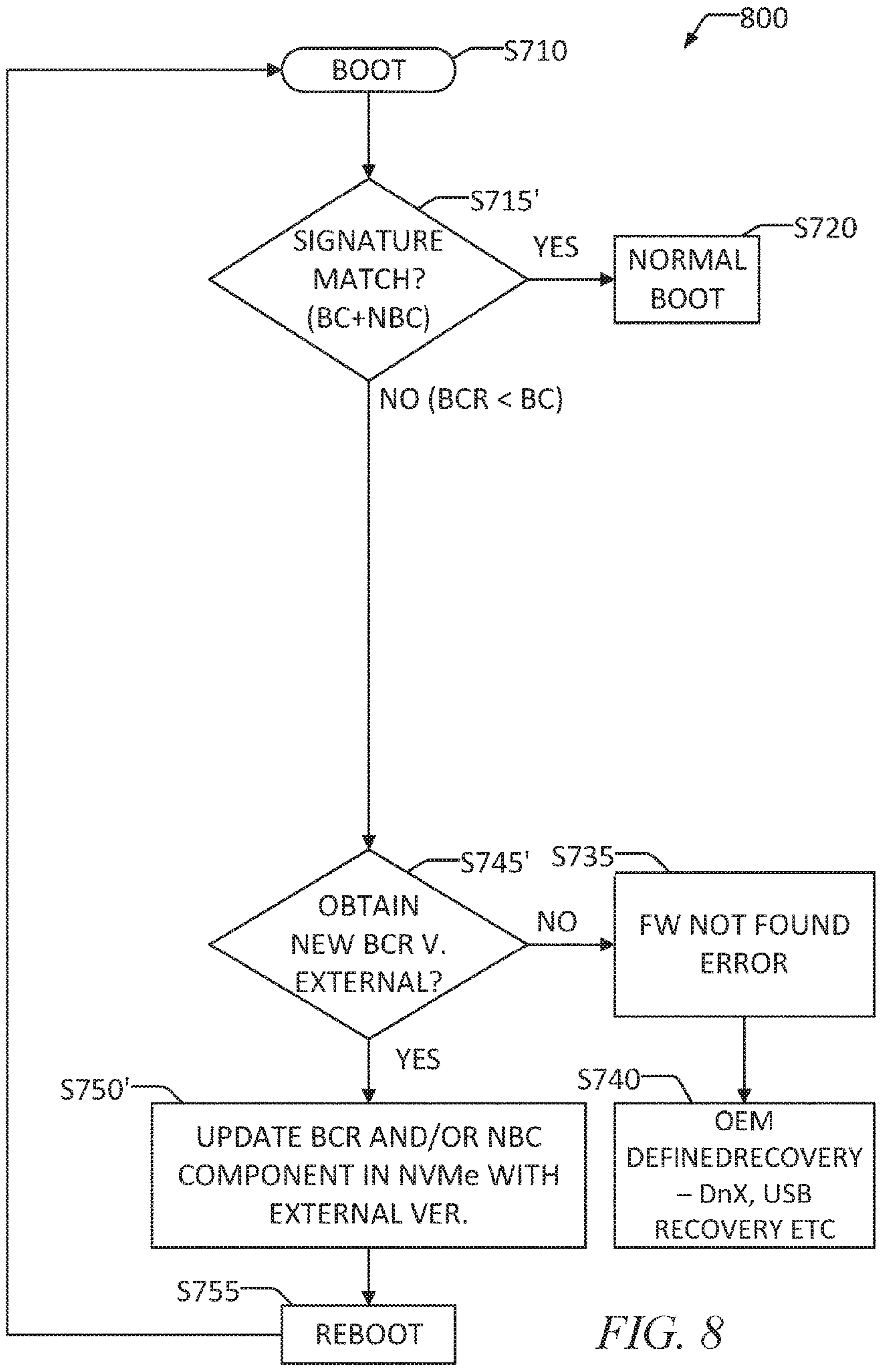

800
S710
BOOT
S715'
SIGNATURE MATCH? (BC+NBC)
YES
S720
NORMAL BOOT
NO (BCR < BC)
S745'
OBTAIN NEW BCR V. EXTERNAL?
NO
S735
FW NOT FOUND ERROR
YES
S750'
UPDATE BCR AND/OR NBC COMPONENT IN NVMe WITH EXTERNAL VER.
S740
OEM DEFINEDRECOVERY – DnX, USB RECOVERY ETC
S755
REBOOT

FIG. 8

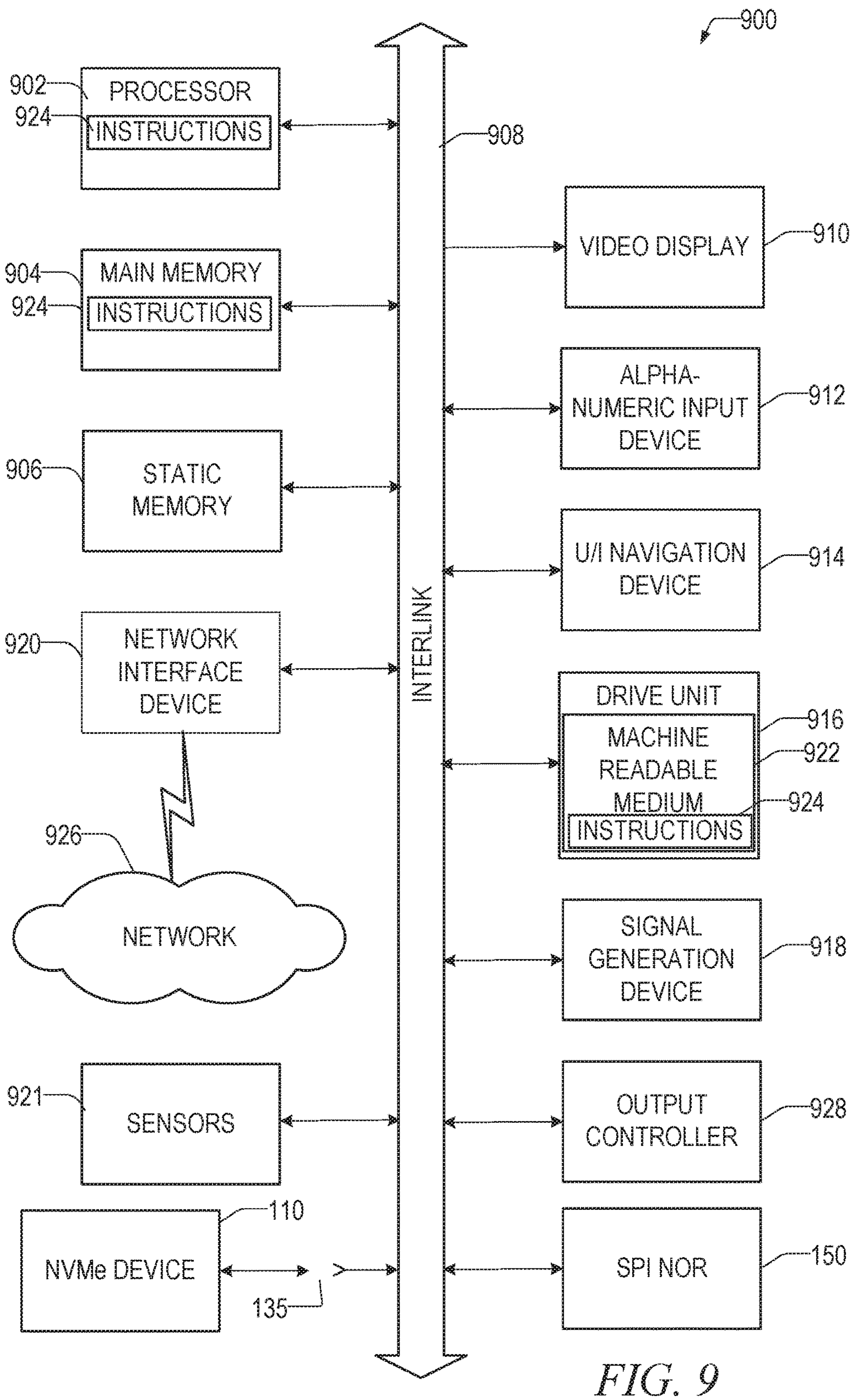

900
902
PROCESSOR
924
INSTRUCTIONS
908
904
MAIN MEMORY
924
INSTRUCTIONS
906
STATIC MEMORY
920
NETWORK INTERFACE DEVICE
926
NETWORK
921
SENSORS
NVMe DEVICE
110
135
INTERLINK
VIDEO DISPLAY
910
ALPHA-NUMERIC INPUT DEVICE
912
U/I NAVIGATION DEVICE
914
DRIVE UNIT
916
MACHINE READABLE MEDIUM
922
924
INSTRUCTIONS
SIGNAL GENERATION DEVICE
918
OUTPUT CONTROLLER
928
SPI NOR
150

FIG. 9

METHOD AND APPARATUS FOR HYBRID FIRMWARE BOOT

The present disclosure relates to boot hardware and related procedures for computers such as personal computers (PCs) and for the provision of a hybrid firmware boot.

BACKGROUND

The boot procedure for a computer is typically executed by code stored partially in a firmware element and partially in block media. Historically, firmware was implemented in read-only memory (ROM), although modern devices typically implement firmware in flash memory, which retains its memory even when power is not applied. Non-volatile Memory Express (NVM Express or NVMe) is a logical device interface specification allowing access to non-volatile storage media attached via a Peripheral Component Interconnect Express (PCI Express or PCIe) bus. The PCIe bus is a high-speed serial computer expansion bus standard that is utilized in many modern PCs. The non-volatile storage media may be flash memory and may be used as solid-state drives (SSDs) for computers.

NVMe NAND technology and NVMe 3D XPoint Block technology media (both being technologies for non-volatile memory) may be designed to support system firmware (FW) specific partitions called "boot partitions" and a secure firmware specific data partition called Replay Protected Memory Block (RPMB). A boot partition is a primary partition containing a piece of software responsible for booting an operating system (OS) (boot loader). An RPMB permits a secure memory block for storing small amounts of secure information, enabling a secure relationship between a host controller and the memory device.

The Serial Peripheral Interface (SPI) is a synchronous serial communications interface typically utilized for short distance communications, and developed by Motorola in the last 1980s. SPI NOR (or Serial NOR) is a type of SPI storage that utilizes non-volatile memory.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block sequence diagram of an example that illustrates a hybrid boot firmware (hybrid FW) store model in which both the NVMe device and the SPI NOR have original versions, in accordance with some aspects of the disclosed subject matter;

FIG. **2** is a block sequence diagram of the hybrid FW store model shown in FIG. **1** where an NVMe device with a newer version is attached but prior to updating the SPI NOR, in accordance with some aspects of the disclosed subject matter;

FIG. **3** is a block sequence diagram of the hybrid FW store model shown in FIG. **2** where an NVMe device with a newer version is attached and after updating the SPI NOR, in accordance with some aspects of the disclosed subject matter;

FIG. **4** is a block sequence diagram of an example that illustrates hybrid FW store model in which both the NVMe device and the SPI NOR have up-to-date versions;

FIG. **5** is a block sequence diagram of the hybrid FW store model shown in FIG. **4** where an NVMe device with an older version is attached;

FIG. **6** is a block sequence diagram of the hybrid FW store model shown in FIG. **5** where the NVMe device has been updated;

FIG. **7** is a flowchart of a process for updating when the boot critical SPI NOR version is less than the version of an NVMe device, in accordance with some aspects of the disclosed subject matter;

FIG. **8** is a flowchart of a process for updating when the boot critical SPI NOR version is greater than the version of an NVMe device, in accordance with some aspects of the disclosed subject matter; and

FIG. **9** is a block diagram illustrating a machine that may be a computer on which various components described herein may reside and processes described herein may be performed, in accordance with some aspects of the disclosed subject matter.

DETAILED DESCRIPTION

The following is a detailed description of various configurations depicted in the accompanying drawings. However, the amount of detail offered is not intended to limit anticipated variations of the described configurations; to the contrary, the claims and detailed description are to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present teachings as defined by the claims. The detailed descriptions below are designed to make such configurations understandable to a person having ordinary skill in the art.

Enabling a complete computer system firmware boot from an NVMe storage device helps reduce costs associated with an SPI NOR on a manufacturer's bill of materials (BOM) for the device. The SPI NOR may be a flash memory, and both the NVME and SPI NOR are non-volatile, meaning they are capable of retaining memory when power is off. A complete system firmware boot from an NVMe boot partition may be beneficial, but require certain changes over existing implementations.

FIGS. **1** to **6** are block sequence diagrams of examples that illustrate sequences of a hybrid boot firmware (hybrid FW) store model (a computer boot apparatus) **100**A-**100**C (reference numbers herein containing letters at the end may be collectively or representatively indicated by the number alone, e.g., **100**A, **100**B and **100**C may be referred to as **100**) that splits the storage of boot instructions used in the boot process between a primary boot component **150** and a secondary boot component **110**. The primary boot component **150**, which may be, for example, fixedly mounted to a motherboard or other system board of a computer, may be configured to initialize a boot of the computer.

FIG. **1** reflects an original configuration of the hybrid FW **100**A with an original NVME **110**A and original SPI NOR **150**A. FIG. **2** reflects a configuration of the hybrid FW **100**B where a user has plugged in a newer version of the NVMe device **110**B, but prior to updating the SPI NOR **150**A. FIG. **3** reflects a configuration of the hybrid FW **100**C with the updated NVMe device **110**B.

The secondary boot component **110**, which may be, for example, removably attached to the computer, may be configured to complete the boot of the computer via a non-critical boot component, discussed below. The terms "fixedly" and "removably", as used herein, are meant to be with relationship to the intended use of a typical consumer using the product, and not with relationship to a repair/maintenance person. Thus, a typical consumer would not be expected to remove components with a soldering iron or pull chips from chip sockets.

As may be seen in FIG. **1**, with the hybrid FW in a first state **100**A, the system firmware (system boot critical firmware (BC FW) or boot critical portion) **152**A may be stored on the primary boot component **150**A, which may be an SPI NOR (e.g., by independent basic input output service (BIOS) vendors). The non-boot-critical firmware portion **130**A, containing non-boot-critical portion instructions may be stored on the secondary boot component **110**A (and which may be the bulk of the secondary boot component), such as block media like an NVMe storage device, and may take advantage of an NVMe boot partition of the NVMe storage device (such as NVME 3D XPoint™). Boot critical components **152** are components that are required for the system to recover if it gets corrupted. Examples may include components for loading microcode on a CPU and memory initialization. Non-boot critical components **130** are platform features and device initialization components. Examples may include components such as hard disk security and touch-panel or touch pad device initialization components. The system may be recovered using boot critical components **152** even if non-boot critical components **130** get corrupted.

This hybrid FW **100** with a split store hybrid boot may reduce the amount of platform flash (SPI NOR) BOM significantly (at the time of this application, 16 MB or 32 MB of SPI NOR flash costs approximately $0.70-1.00; reducing the SPI NOR flash to 4 MB may reduce its cost to $0.30). This may be advantageous in modern systems where the SPI flash size has been increasing rapidly to handle greater functionality. One issue related to the hybrid FW is that NVMe comes in various form factors, including a detachable/removable form factor that may plug into a bus **140** of the PC. Therefore, it is important to maintain boot capability and data integrity on NVMe devices **110**A when they replaced/removed.

The system described herein may provide, for example: data integrity between the NVMe storage device **110**A and the SPI NOR **150**A (initial firmware boot storage), a seamless and better user experience on an upgrade/portability/recovery mechanism for removable NVMe storage/boat devices **110**A, version management between NVMe storage device **110**A upgrades, an authenticated split stored firmware (SPI-NOR and NVMe) pair, and a reduced firmware upgrade cost in manufacturing when upgrading the NVMe storage device **110**A on platforms.

This may be achieved by, for example, implanting an intelligent sync (boot policy) manager component **156**A in system firmware layout in the initial BC firmware image **152**A which resides on the SPI NOR **150**A that may be hardwired onto a motherboard of a PC. The sync (policy) manager component **156**A residing in the boot critical (BC) component **150**A may be responsible for: verifying/authenticating the non-boot critical (NBC) FW image **130**A in the NVMe storage device **110**A, version management between the split storage device (SPI NOR **150**A and NVMe **110**A), and ensuring that both FW image versions (via version identifiers **112**A, **154**A) are in sync. As illustrated in FIG. **1**, version identifiers **112**A, **154**A are alphanumeric values, however, these identifiers may be in any form, including text, that permits a determination to be made as to whether the versions are the same or whether one version is a later version than the other. A boot critical recovery (BCR) **120**A portion or component (that may be a kind of a duplicate copy of the BC component **152**) may be included on the NVMe device **110**A that may be copied or translated to the SPI NOR **150**A, discussed in more detail below.

The sync manager **156**A may verify, in addition to a version number, that the NBC **130**A is the matching pair element to the BC **150**A, based on brand compatibility or other criteria. For example, a user may use a Dell® NVMe drive with a Dell® NBC on a Lenovo® system, since the NVMe storage is the removable device. The sync manager **156**A in the Lenovo® system's SPI NOR (the BC component) may verify that NBC in NVMe is the correct element for the matching pair. The same applies within the same OEM but for different generation of platforms. For example, a user should not attempt to install a newer Intel generation of an NBC NVMe and boot it with an older Intel generation platform. Additionally, the sync manager **156**A may perform a data integrity check to verify that the NBC image is not corrupted or modified in order to prevent a security attack. The data integrity check may utilize, for example, the Intel® Authenticated Code Module (ACM)-based secure boot that verifies a known and trusted BIOS is booting the platform, as well as the Intel® Platform Protection Technology with BIOS Guard, which provides hardware-assisted authentication and protection against BIOS recovery attacks. This data integrity check may also be part of the sync manager **156**A to verify and protect the integrity of the NBC **130** in the NVMe storage **110**.

The sync manager **156**A, which may reside on the BC firmware (SPI NOR **150**A), may version check and verify the BCR portion **112**A on the removable storage media (NVMe device **110**A) boot partition and maintain a secure sync between the BCR portion **120**A, containing information to update the SPI NOR **150**A, and the BC component **152**A and its instructions on the SPI NOR **150**A for performing the initial part of the boot

If the verification is successful (e.g., the versions match), the PC may try to boot from the NVMe storage device **110**. If the verification does not pass, then the system may decide whether to enable upgrade or downgrade the system program(s), e.g., the BC component **152**, the sync manager **156**, and the NBC **130**.

The sync manager **156**A may perform a secure update by the entity having a lower version in the case of a version mismatch. With an NVMe storage solution used in memory intensive applications, such as in-memory databases, cloud computing applications, the solution provided herein enables those in the storage industry to provide a seamless user experience, and a reliable and secure solution for firmware storage.

In some situations, the version stored on the NVMe storage device may be updated, such as when a software upgrade occurs. A new V2 version **112**B of the software is illustrated in FIG. **2**. As shown in FIG. **2**, if the versions are out of sync, and the NVMe device **1108** has a higher version number **112**B (V**2** versus V**1** for the BC component **152**A of the SPI NOR **150**A), the sync manager **156**A component locates the newer version of the BCR portion **120**B and/or NBC component **13013** in the NVMe device **110**B and updates **170** the BC component **152**A in the initial FW boot device (SPI NOR) **150**A. The end result may be seen in FIG. **3**, where the BC component **152**B in the SPI NOR. **150**B has been updated to V**2** **154**B. The update may or may not include the sync manager **156**B.

FIGS. **4**-**6** are sequence diagrams of an example hybrid FW **100** being updated when an older version of the NVMe device **110**A is plugged into a newer version SPI NOR. **150**B.

FIG. **4** reflects an up-to-date configuration of the hybrid FW **100**B with an up-to-date NVME **110**B and up-to-date SPI NOR **150**B. FIG. **5** reflects a configuration of the hybrid FW **100**A where a user has plugged in an older version of the NVMe device **110**A, but prior to it being updated. FIG. **6** reflects a configuration of the hybrid FW **100**C with the updated NVMe device **110**B.

Referring to FIGS. **4** to **6**, if versions **112**A, **154**B are out of sync, as illustrated in FIG. **5**, and the NVMe device **110**A has a BCR **120**A with a lower version number than the BC component **152**B in the SPI NOR **150**B, different options may be considered. In one implementation, the sync manager **156**B may request user input or a user selection to let the user decide on an update action, such as to update the NVMe **110**A or the BC component **152**B version using the BCR in the NVMe, or download a new version for the NVMe or the BC component **152**B from an external source **180** (such as via Universal Serial Bus (USB), Intel Download and Execute DnX®, Wi-Fi, or Intel® Active Management Technology (AMT)). The user input or user selection for update actions can similarly be utilized in the design illustrated in FIGS. **1** to **3** when the NVMe device **110**B has a BCR **12**B with a higher number than the BC component **152**A in the SPI NOR **150**A. The user input may indicate a source of the update, a target of the update (either expressly or implicitly—that is, if the source of the update is the BCR **120**, then the target of the update may implicitly be the BC component **152**). When the BC component is updated, the sync manager **156** may be updated as well, or, in an implementation, the sync manager **156** may be updated using any of the techniques discussed above independently of the BC component **152**.

Other ways to update the NVMe **110**A with the BC component **152**B in place may be to utilize universal serial bus (USB), serial AT attachment (SATA), embedded multimedia controller (eMMC), universal flash storage (UFS), or any storage device from which the BC component **152**B driver is able to read. Additionally, the NVMe component **110**B driver may be downloaded over a wireless interface, such as or Bluetooth. The location may be implementation specific, and, for example, an OEM may simply search in one or more established locations or use one or more established protocols. For example, the search may be for a filename "abcd.rom" in the storage device EFI file system, where "abed" is a manufacturer's name.

The sync manager **156**B may receive the user selection and perform the user-selected operations. If the BC component **150**B is unable to locate the NBC component **130**A, or finds incompatible FW in the NVMe device **110**A, the sync manager **156**B may inform the user of the error in an error procedure, and enable NBC **130**A recovery options via USB/Secure Digital (SD) card devices. This provides a good upgrade model for computer system providers without the need for extra hardware for removable NVMe devices **110** on a system. In one implementation, it may be possible to downgrade the BC component **152**B and/or the policy manager **156**B on the SPI NOR **150**B to be compatible. This is a choice that an OEM may decide to let the user make.

If a new model NVMe Device **110** is plugged into the PC that is not at all compatible or an upgrade is not able to be located, the sync manager **156** may indicate that an error has occurred or provide an error handling mechanism. In order for the sync manager **156** to determine whether there is a mismatch or not, it may read future versions of the NVMe device. Therefore, it is desirable that future versions of the NVMe devices have some commonality/consistency (e.g., location and format of the version number) to ensure earlier versions of the sync manager **156** may read them.

FIG. **7** is a flowchart of a process **700** for updating when the boot critical SPI NOR version is less than the version of an NVMe device, in accordance with some aspects of the disclosed subject matter. The process **700** begins with a boot operation **S710**. At some point in the boot up, the sync manager **156** may, at operation **S715**, verify some form of a version or signature match between the BC component **152** and the NBC **130**. If they match (**S715**:Yes), then a normal boot S720 may take place.

If they do not match (**S715**:No), and the BC component **152** version is lower than the BCR **120** or NBC **130** in the block media element or NVMe **110**, then the sync manager **156** may initiate a BC FW update in operation **S725**. This may be achieved by locating, in operation **S730**, the BCR **120** in the block media **110**. If the BCR **120** is unable to be located in the block media, a "not found" error may be generated in operation S735, and some form of recovery operation **S740** may be initiated. If the BCR **120** is located in the block media, then compatibility is checked S**745**. If the located BCR **120** is not compatible with the BC component **152** (**S745**:No), then the error handling of operations S735 and S740 may be invoked. Otherwise (**S745**:Yes), the BC component **152** in the SPI NOR **150** may be updated with the BCR **120** (**S750**), and the system rebooted **S755**.

In sum, according to an implementation, the version compare may be between the BC component **152** and either/both of the BCR **120** and the NBC **130**. The BCR **120** may update the BC component **152** with its own data, but if the BC component **152** does not update the BCR **120** with its own data, and when the BCR **120** and/or NBC **130** is updated, there is some external source for the update.

FIG. **8** is a flowchart of a process **800** similar to the process **700** of FIG. **7**, but shows a different flow if, at operation **S715'**, the BCR **120** or NBC **130** version is lower than the BC component **152** version. In this case, it is determined, at operation **S745'** whether a new BCR **120** and NBC **130** may be obtained from some external source, as described above. If so (**S745'**:Yes), then the BCR **120** and/or NBC **130** component may be updated accordingly (**S750'**). If not (**S745'**:No), then the error handling as described above is undertaken at operation **S735**.

FIG. **9** is a block diagram illustrating a machine that may be a computer on which various components described herein may reside and processes described herein may be performed. The machine (e.g., computer) **900** may include the SPI NOR **150** and a physical connector **135** for the NVMe device **110** that connects this device to the machine **900**. The machine **900** may include a hardware processor **902** (e.g., a central processing unit (CPU), which may be an implementation of the processor **922** discussed above, a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory **904** and a static memory **906**, which may be an implementation of the memory **924** discussed above, some or all of which may communicate with each other via an interlink (e.g., bus) **908** (which may be the bus **140**, discussed above). The machine **900** may further include a display unit **910**, an alphanumeric input device **912** (e.g., a keyboard), and a user interface (UI) navigation device **914** (e.g., a mouse). In an example described herein, the display unit **910**, input device **912** and UI navigation device **914** may be a touch screen display. The machine **900** may additionally include a storage device **916** (e.g., drive unit, which may be a part of the NVMe device **110**), a signal generation device **918** (e.g., a speaker), a network interface device **920**, and one or more sensors **921**, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor. The machine **900** may include an output controller **928**, such as a serial (e.g., universal serial bus (USB)), parallel, or other wired or wireless (e.g., infrared(IR), near field communication (NFC), etc.) controller connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.).

The storage device **916** may include a machine readable medium **922** on which is stored one or more sets of data structures or instructions **924** (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. The instructions **924** may also reside, completely or at least partially, within the main memory **904**, within static memory **906**, or within the hardware processor **902** during execution thereof by the machine **900**. In an example, one or any combination of the hardware processor **902**, the main memory **904**, the static memory **906**, or the storage device **916** may constitute machine readable media.

While the machine readable medium **922** is illustrated as a single medium, the term "machine readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions **924**.

The term "machine readable medium" may include any medium that is capable of storing, encoding, or carrying instructions for execution by the machine **900** and that cause the machine **900** to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting machine readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of machine readable media may include: non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); Solid State Drives (SSD); and CD-ROM and DVD-ROM disks. In some examples, machine readable media may include non-transitory machine readable media. In some examples, machine readable media may include machine readable media that is not a transitory propagating signal.

The instructions **924** may further be transmitted or received over the communications network **926** using a transmission medium via the network interface device **920**. The term "transmission medium" is defined herein to include any medium that is capable of storing, encoding, or carrying instructions for execution by the machine, and includes digital or analog communications signals or other medium to facilitate communication of such software.

The machine **900** may communicate with one or more other machines **900** utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communication networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Institute of Electrical and Electronics Engineers (IEEE) 802.11 family of standards known as Wi-Fi®, WiGig®, IEEE 802.16 family of standards known as WiMax®), IEEE 802.15.4 family of standards, a Long Term Evolution (LTE) family of standards, a Universal Mobile Telecommunications System (UMTS) family of standards, peer-to-peer (P2P) networks, virtual private networks (VPN), or any other way of transferring data between machines **900**. In an example, the network interface device **920** may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network **926**.

In an example, the network interface device **920** may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output (SIMO), multiple-input multiple-output (MIMO), or multiple-input single-output (MISO) techniques. In some examples, the network interface device **920** may wirelessly communicate using Multiple User MIMO techniques.

A wide variety of computing devices may constitute a machine **900**, as described herein. The following list includes a variety of devices that may fit the definition of a machine **900**: a personal data assistant (PDA), a cellular telephone, including a smartphone, a tablet computing device, a laptop computer, a desktop computer, a workstation, a server computer, a mainframe computer, and the like.

For the purposes of promoting an understanding of the principles of this disclosure, reference has been made to the various configurations illustrated in the drawings, and specific language has been used to describe these configurations. However, no limitation of the scope of the inventive subject matter is intended by this specific language, and the inventive subject matter should be construed to encompass all aspects and configurations that would normally occur to one of ordinary skill in the art. The configurations herein may be described in terms of functional block components and various processing steps. Such functional blocks may be realized by any number of components that perform the specified functions. The particular implementations shown and described herein are illustrative examples and are not intended to otherwise limit the scope of the inventive subject matter in any way. The connecting lines, or connectors shown in the various figures presented may, in some instances, be intended to represent example functional relationships and/or physical or logical couplings between the various elements. However, many alternative or additional functional relationships, physical connections or logical connections may be present in a practical device. Moreover, no item or component is essential unless the element is specifically described as "essential" or "critical". Numerous modifications and adaptations will be readily apparent to those skilled in this art.

EXAMPLES

Example 1 is a computer boot apparatus for controlling a computer boot up procedure, comprising: a primary boot component that is fixedly mounted in a computer, comprising: a firmware element that is a non-volatile memory, comprising: a boot critical portion comprising instructions that, when executed on a processor, initiate a boot of the computer; a first version identifier; and a policy manager; wherein: the primary boot component is to initialize the boot of the computer via the boot critical portion; and the policy manager is to verify and authenticate a secondary boot component that is removably attached to the computer.

In Example 2, the subject matter of Example 1 optionally includes wherein policy manager is to verify and authenticate the secondary boot component to: compare the first version identifier via a second version identifier of the secondary boot component; when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot with a non-critical boot component stored within the secondary boot component; and when the first version identifier is less than the second version identifier, then update the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and perform a reboot of the computer.

In Example 3, the subject matter of any one or more of Examples 1-2 optionally include wherein the policy manager is to verify and authenticate the secondary boot component to: compare the first version identifier with a second version identifier of the secondary boot component; when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot with a non-critical boot component stored within the secondary boot component; and when the first version identifier is greater than the second version identifier, then update the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and perform a reboot of the computer.

In Example 4, the subject matter of any one or more of Examples 1-3 optionally include wherein the policy manager is to verify and authenticate the secondary boot component to: compare the first version identifier with a second version identifier of the secondary boot component; when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot with a non-critical boot component stored within the secondary boot component; and when the first version identifier is greater than the second version identifier, then update the secondary boot component based on information from an external source and perform a reboot of the computer.

In Example 5, the subject matter of any one or more of Examples 1-4 optionally include wherein the policy manager is to: request user input related to an update to the primary boot component or the secondary boot component; receive a user selection related to the update; and perform an update action based on the received user selection.

In Example 6, the subject matter of Example 5 optionally includes wherein the user selection is selected from: perform an update of the secondary boot component based on information from an external source; perform an update of the secondary boot component based on information in the primary boot component; perform an update of the primary boot component based on information in the secondary boot component; and perform an update of the primary boot component based on information from the external source.

In Example 7, the subject matter of any one or more of Examples 3-6 optionally include wherein the policy manager is to: execute an error procedure when the secondary boot component is determined to be incompatible with the primary boot component or an upgrade is unable to be located.

In Example 8, the subject matter of any one or more of Examples 1-7 optionally include wherein an external source comprises one of a Universal Serial Bus device, Intel Download and Execute DnX®, a wireless interface, or Active Management Technology.

In Example 9, the subject matter of any one or more of Examples 1-8 optionally include wherein the wireless interface comprises one of Wi-Fi or Bluetooth.

In Example 10, the subject matter of any one or more of Examples 1-9 optionally include wherein the primary boot component utilizes a Serial Peripheral Interface NOR component.

In Example 11, the subject matter of any one or more of Examples 1-10 optionally include the secondary boot component, comprising: a block media element that is a non-volatile memory, comprising: a non-boot critical portion

comprising instructions that are executed after the boot critical portion instructions; and a boot critical recovery portion comprising information to update the primary boot component.

In Example 12, the subject matter of Example 11 optionally includes wherein the secondary boot component utilizes a Non-volatile Memory Express (NVMe) component.

Example 13 is a method for operating a computer boot apparatus to control a computer boot up procedure, the computer boot apparatus comprising: a primary boot component that is fixedly mounted in a computer and has a firmware element that is a non-volatile memory, comprising: a boot critical portion comprising boot instructions executable on a processor of the computer; a first version identifier; and a policy manager; the method comprising: initializing a boot of the computer utilizing the boot critical portion; and verifying and authenticating, with the policy manager, a secondary boot component that is removably attached to the computer.

In Example 14, the subject matter of Example 13 optionally includes comparing, by the policy manager, the first version identifier with a second version identifier of the secondary boot component, the secondary boot component comprising a block media element that is a non-volatile memory; when the first version identifier and the second version identifier are equal, then completing the initializing of the boot and allowing the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and when the first version identifier is less than the second version identifier, then updating the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and performing a reboot of the computer.

In Example 15, the subject matter of Example 14 optionally includes allowing access of the boot critical recovery portion of the secondary boot component to the policy manager of the primary boot component; and completing the boot based on a non-boot-critical portion of the secondary boot component.

In Example 16, the subject matter of Example 15 optionally includes wherein: the primary boot component utilizes a Serial Peripheral Interface NOR component; and the secondary boot component utilizes a Non-volatile Memory Express (NVMe) component.

In Example 17, the subject matter of any one or more of Examples 13-16 optionally include comparing the first version identifier with a second version identifier of the secondary hoot component; when the first version identifier and the second version identifier are equal, then completing the initialize of the boot and allowing the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and when the first version identifier is greater than the second version identifier, then updating the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and performing a reboot of the computer.

In Example 18, the subject matter of any one or more of Examples 13-17 optionally include comparing the first version identifier with a second version identifier of the secondary boot component; when the first version identifier and the second version identifier are equal, then completing the initialize of the boot and allowing the secondary boot component to continue the boot using a non-critical hoot component stored within the secondary boot component; and when the first version identifier is greater than the second version identifier, then updating the secondary boot component based on information from an external source and performing a reboot of the computer.

In Example 19, the subject matter of any one or more of Examples 13-18 optionally include by the policy manager: requesting user input related to an update to the primary boot component or the secondary boot component; receiving a user selection related to the update; and performing an update action based on the received user selection.

In Example 20, the subject matter of Example 19 optionally includes wherein the user selection is selected from: performing an update of the secondary boot component based on information from an external source; performing an update of the secondary boot component based on information in the primary boot component; performing an update of the primary boot component based on information in the secondary boot component; and performing an update of the primary boot component based on information from the external source.

In Example 21, the subject matter of any one or more of Examples 17-20 optionally include by the policy manager: executing an error procedure when the secondary boot component is determined to be incompatible with the primary boot component or an upgrade is unable to be located.

In Example 22, the subject matter of any one or more of Examples 13-21 optionally include wherein an external source comprises one of a Universal Serial Bus device, Intel Download and Execute DnX®, a wireless interface, or Active Management Technology.

In Example 23, the subject matter of any one or more of Examples 13-22 optionally include wherein the wireless interface comprises one of Wi-Fi or Bluetooth.

In Example 24, the subject matter of any one or more of Examples 13-23 optionally include wherein the primary boot component utilizes a Serial Peripheral Interface NOR component.

In Example 25, the subject matter of any one or more of Examples 13-24 optionally include wherein: the secondary boot component comprises: a block media element that is a non-volatile memory and comprises: a non-boot critical portion comprising instructions that are executed after the boot critical portion instructions; and a boot critical recovery portion comprising information to update the primary boot component.

In Example 26, the subject matter of Example 25 optionally includes wherein the secondary boot component utilizes a Non-volatile Memory Express (NVMe) component.

Example 27 is a computer program product that is a primary boot component for controlling a computer boot up procedure comprising at least one computer readable storage media comprising computer-executable instructions operable to, when executed by processing circuitry of a computer, configure the computer to: initialize a boot of the computer via a boot critical portion of the primary boot component; and verify and authenticate, with a policy manager of the primary boot component, a secondary boot component that is removably attached to the computer.

In Example 28, the subject matter of Example 27 optionally includes wherein the instructions are further operable to: compare, by the policy manager, a first version identifier of the primary boot component with a second version identifier of a secondary boot component, the secondary boot component comprising a block media element that is a non-volatile memory; when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot via a non-critical boot component stored within the secondary boot component; and when

the first version identifier is less than the second version identifier, then update the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and perform a reboot of the computer.

In Example 29, the subject matter of any one or more of Examples 27-28 optionally include wherein the instructions are further operable to: compare, by the policy manager, a first version identifier with a second version identifier of the secondary boot component; when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and when the first version identifier is greater than the second version identifier, then update the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and perform a reboot of the computer.

In Example 30, the subject matter of any one or more of Examples 27-29 optionally include wherein the instructions are further operable to: compare, by the policy manager, a first version identifier with a second version identifier of the secondary boot component; when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and when the first version identifier is greater than the second version identifier, then update the secondary boot component based on information from an external source and perform a reboot of the computer.

In Example 31, the subject matter of any one or more of Examples 27-30 optionally include wherein: the primary boot component utilizes a Serial Peripheral Interface NOR component; and the secondary boot component utilizes a Non-volatile Memory Express (NVMe) component.

Example 32 is a computer program product comprising at least one computer readable storage media comprising computer-executable instructions operable to, when executed by processing circuitry of a device, configure the apparatus to perform any of the methods of Examples 13-26 for controlling a computer boot up procedure.

Example 33 is a computer boot apparatus for controlling a computer boot up procedure, comprising: a processor; a bus; a user interface; and a primary boot component that is fixedly mounted in the computer, and connected to the computer via the bus, the primary boot component comprising: a firmware element that is a non-volatile memory, comprising: a boot critical portion comprising instructions that, when executed on the processor, initiate a boot of the computer; a first version identifier; and a policy manager; wherein: the primary boot component is to initialize a boot of the computer utilizing the boot critical portion; and the policy manager is to verify and authenticate a secondary boot component that is removably attached to the computer.

In Example 34, the subject matter of Example 33 optionally includes the secondary boot component, comprising: a block media element that is a non-volatile memory, comprising: a non-boot critical portion comprising instructions that are executed after the boot critical portion instructions; and a boot critical recovery portion comprising information to update the primary boot component.

Example 35 is a system for controlling a computer boot up procedure comprising means to perform any of the methods of Examples 13-26.

Example 36 is a computer boot apparatus that performs an initial boot up sequence of a computer, comprising: a primary boot component that is fixedly mounted in a computer and has a firmware element that is a non-volatile memory, comprising: a boot critical portion comprising boot instructions executable on a processor of the computer; a first version identifier; and a policy manager; means for initializing a boot of the computer utilizing the boot critical portion; and means for verifying and authenticating, with the policy manager, a secondary boot component that is removably attached to the computer.

In Example 37, the subject matter of Example 36 optionally includes means for comparing, by the policy manager, the first version identifier with a second version identifier of the secondary boot component, the secondary boot component comprising a block media element that is a non-volatile memory; means for, when the first version identifier and the second version identifier are equal, then completing the initializing of the boot and allowing the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and means for, when the first version identifier is less than the second version identifier, then updating the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and performing a reboot of the computer.

In Example 38, the subject matter of Example 37 optionally includes means for allowing access of the boot critical recovery portion of the secondary boot component to the policy manager of the primary boot component; and means for completing the boot based on a non-boot-critical portion of the secondary boot component.

In Example 39, the subject matter of Example 38 optionally includes wherein: the primary boot component utilizes a Serial Peripheral Interface NOR component; and the secondary boot component utilizes a Non-volatile Memory Express (NVMe) component.

In Example 40, the subject matter of any one or more of Examples 36-39 optionally include means for comparing the first version identifier with a second version identifier of the secondary boot component; means for, when the first version identifier and the second version identifier are equal, then completing the initialize of the boot and allowing the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and means for, when the first version identifier is greater than the second version identifier, then updating the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and performing a reboot of the computer.

In Example 41, the subject matter of any one or more of Examples 36-40 optionally include means for comparing the first version identifier with a second version identifier of the secondary boot component; means for, when the first version identifier and the second version identifier are equal, then completing the initialize of the boot and allowing the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and means for, when the first version identifier is greater than the second version identifier, then updating the secondary boot component based on information from an external source and performing a reboot of the computer.

Example 42 is at least one machine-readable medium including instructions, which when executed by a machine, cause the machine to perform operations of any of the operations of Examples 1-41.

Example 43 is an apparatus comprising means for performing any of the operations of Examples 1-41.

Example 44 is a system to perform the operations of any of the Examples 1-41.

Example 45 is a method to perform the operations of any of the Examples 1-41.

The invention claimed is:

1. A computer boot apparatus for controlling a computer boot up procedure, comprising:
- a primary boot component that is fixedly mounted in a computer, comprising:
  - a firmware element that is in a non-volatile memory, comprising:
    - a boot critical portion comprising instructions that, when executed on a processor, initiate a boot of the computer;
    - a first version identifier; and
    - a policy manager;
- wherein
  - the primary boot component is to initialize the boot of the computer via the boot critical portion;
  - the policy manager is to verify and authenticate a secondary boot component that is removably attached to the computer;
  - the primary boot component utilizes a Serial Peripheral Interface NOR component; and
  - the secondary boot component utilizes a Non-volatile Memory Express (NVMe) component.

2. The computer boot apparatus of claim **1**, wherein policy manager is to verify and authenticate the secondary boot component to:
- compare the first version identifier with a second version identifier the secondary boot component;
- when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot with a non-critical boot component stored within the secondary boot component; and
- when the first version identifier is less than the second version identifier, then update the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and perform a reboot of the computer.

3. The computer boot apparatus of claim **1**, wherein the policy manager is to verify and authenticate the secondary boot component to:
- compare the first version identifier with a second version identifier of the secondary boot component;
- when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot with a non-critical boot component stored within the secondary boot component; and
- when the first version identifier is greater than the second version identifier, then update the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and perform a reboot of the computer.

4. The computer boot apparatus of claim **1**, wherein the policy manager is to verify and authenticate the secondary boot component to:
- compare the first version identifier with a second version identifier of the secondary boot component;
- when the first version identifier d the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to

continue the boot with a non-critical boot component stored within the secondary boot component; and

when the first version identifier is greater than the second version identifier, then update the secondary boot component based on information from an external source and perform a reboot of the computer.

5. The computer boot apparatus of claim **1**, wherein the policy manager is to:

request user input related to an update to the primary boot component or the secondary boot component;

receive a user selection related to the update; and

perform an update action based on the received user selection.

6. The computer boot apparatus of claim **5**, wherein the user selection is selected from:

perform an update of the secondary boot component based on information from an external source;

perform an update of the secondary boot component based on information in the primary boot component;

perform an update of the primary boot component based on information in the secondary boot component; and

perform an update of the primary boot component based on information from the external source.

7. The computer boot apparatus of claim **3**, wherein the policy manager is to:

execute an error procedure when the secondary boot component is determined to be incompatible with the primary boot component or an upgrade is unable to be located.

8. The computer boot apparatus of claim **1**, wherein an external source comprises one of a Universal Serial Bus device, a wireless interface, or Active Management Technology.

9. The computer boot apparatus of claim **1**, wherein the wireless interface comprises Wi-Fi.

10. The computer boot apparatus of claim **1**, further comprising:

the secondary boot component, comprising:

a block media element that is in a non-volatile memory, comprising:

a non-boot critical portion comprising instructions that are executed after the boot critical portion instructions; and

a boot critical recovery portion comprising information to update the primary boot component.

11. A method for operating a computer boot apparatus to control a computer boot up procedure, the computer boot apparatus comprising:

a primary boot component that is fixedly mounted in a computer and has a firmware element that is in a non-volatile memory, wherein the primary boot component utilizes a Serial Peripheral Interface NOR component, comprising:

a boot critical portion comprising boot instructions executable on a processor of the computer;

a first version identifier; and

a policy manager;

the method comprising:

initializing a boot of the computer utilizing boot critical portion; and

verifying and authenticating, with the policy manager, a secondary boot component that is removably attached to the computer, wherein the secondary boot component utilizes a Non-volatile Memory Express (NVMe) component.

12. The method of claim **11**, further comprising:

comparing, by the policy manager, the first version identifier with a second version identifier of the secondary boot component, the secondary boot component comprising a block media element that is in a non-volatile memory;

when the first version identifier and the second version identifier are equal, then completing the initializing of the boot and allowing the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and

when the first version identifier is less than the second version identifier, then updating the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and performing a reboot of the computer.

13. The method of claim **12**, further comprising:

allowing access of the boot critical recovery portion of the secondary boot component to the policy manager of the primary boot component; and

completing the boot based on a non-boot-critical portion of the secondary boot component.

14. The method of claim **11**, further comprising:

comparing the first version identifier with a second version identifier of the secondary boot component;

when the first version identifier and the second version identifier are equal, then completing the initialization of the boot and allowing the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and

when the first version identifier is greater than the second version identifier, then updating the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and performing a reboot of the computer.

15. The method of claim **11**, further comprising:

comparing the first version identifier with a second version identifier of e secondary boot component;

when the first version identifier and the second version identifier are equal, then completing the initialize of the boot and allowing the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and

when the first version identifier is greater than the second version identifier, then updating the secondary boot component based on information from an external source and performing a reboot of the computer.

16. A non-transitory computer program product that is a primary boot component for controlling a computer boot up procedure comprising at least one computer readable storage media comprising computer-executable instructions operable to, when executed by processing circuitry of a computer, configure the computer to:

initialize a boot of the computer via a boot critical portion of the primary boot component, wherein he primary boot component utilizes a Serial Peripheral Interface NOR component; and

verify and authenticate, with a policy manager of the primary boot component, a secondary boot component that is removably attached to the computer, wherein the secondary boot component utilizes a Non-volatile Memory Express (NVMe) component.

17. The non-transitory computer program product of claim **16**, wherein the instructions are further operable to:

compare, by the policy manager, a first version identifier of the primary boot component with second version identifier of a secondary boot component, the secondary boot component comprising a block media element that is in a non-volatile memory;

when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot via a non-critical boot component stored within the secondary boot component; and

when the first version identifier is less than the second version identifier, then update the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and perform a reboot of the computer.

18. The non-transitory computer program product of claim **16**, wherein the instructions are further operable to:

compare, by the policy manager, a first version identifier with a second version identifier of the secondary boot component;

when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and

when the first version identifier is greater than the second version identifier, then update the boot critical portion based on information stored in a boot critical recovery portion of the secondary boot component and perform a reboot of the computer.

19. The non-transitory computer program product of claim **16**, wherein the instructions are further operable to:

compare, by the policy manager, a first version identifier with a second version identifier of the secondary boot component;

when the first version identifier and the second version identifier are equal, then complete the initialization of the boot and allow the secondary boot component to continue the boot using a non-critical boot component stored within the secondary boot component; and

when the first version identifier is greater than the second version identifier, then update the secondary boot component based on information from an external source and perform a reboot of the computer.

20. A computer boot apparatus for controlling a computer boot up procedure, comprising:

a processor;

a bus;

a user interface; and

a primary boot component that is fixedly mounted in the computer, and connected to the computer via the bus, the primary boot component comprising:

a firmware element that is in a non-volatile memory, comprising:

a boot critical portion comprising instructions that, when executed on the processor, initiate a boot of the computer;

a first version identifier; and

a policy manager;

wherein:

the primary boot component is to initialize a boot of the computer utilizing the boot critical portion;

the policy manager is to verify and authenticate a secondary boot component that is removably attached to the computer;

the primary boot component utilizes a Serial Peripheral Interface NOR component; and

the secondary boot component utilizes a Non-volatile Memory Express (NVMe) component.

21. The computer boot apparatus of claim **20**, further comprising:

the secondary boot component, comprising:

a block media element that is in a non-volatile memory, comprising:

a non-boot critical portion comprising instructions that are executed after the boot critical portion instructions; and

a boot critical recovery portion comprising information to update the primary boot component.

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